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GRADIENT COIL SYSTEM AND METHOD FOR THE PRODUCTION THEREOF

The invention concerns a gradient coil system and a method for the production of the gradient coil system.

Magnetic resonance technology is a known technology to, among other things, acquire images of the inside of a body of an examination subject. Rapidly-switched gradient fields that are generated by a gradient coil system are thereby superimposed on a static basic magnetic field that is generated by a basic field magnet. The magnetic resonance apparatus also comprises a radio-frequency system that radiates radio-frequency signals into the examination subject to excite magnetic resonance signals and that acquires the excited magnetic resonance signals on the basis of which magnetic resonance images are generated.

The gradient coil system is normally comprised of a plurality of coil layers situated one atop the other, whereby the individual coil layers exhibit a complex geometry, are wound forward [sic[in one plane, are mounted atop one another together with insulation layers and are subsequently cast with the gradient coil system under vacuum with a thermosetting casting resin based on epoxy resin. For dissipation of waste heat, additional layers made up of coolant tubes or, respectively, coolant pipes are inserted through which a coolant medium (for example coolant water) flows later in operation. Furthermore it is also known to introduce additional layers for shim coils into the gradient coil system. In the case of an essentially hollow-cylindrical gradient coil system, the first planar finished coil segments are curved into the shape of a cylinder segment and correspondingly introduced into the gradient coil system. Given the production method described in the preceding it is in particular disadvantageous (with regard to the later assembly capability) that the individual coil layers are limited in terms of design to an essentially two-dimensional design. A higher production cost also arises for the assembly of approximately nine coil layers with insulation and reinforcement layers belonging

thereto. Furthermore, the contacting between the individual coil layers with up to approximately 500 solder points per gradient coil system is very elaborate.

It is therefore an object of the invention to achieve a gradient coil system in which aforementioned disadvantages are avoided.

The object is inventively achieved via the subject matter of the claim 1 and via the method according to claim 5. Advantageous embodiments are described in the sub-claims.

According to claim 1, in a gradient coil system of a magnetic resonance apparatus at least one part of an electrical conductor arrangement of the gradient coil system is produced via action of a radiation (in particular laser radiation) on a metal powder sinter material.

Relative to the known methods, the following advantages are therewith achieved: in a construction volume available for the gradient coil system, an arbitrary course of the electrical conductors can be selected without consideration of the technical production requirements, whereby previous designs classified as unrealizable in terms of production technology can be realized simply. A three-dimensional design plan of the electrical conductor courses of the gradient coil system can be directly adopted for the production method. Each change of the course of the electrical conductors can be translated without adaptation of production means, whereby (among other things) a time savings is achieved in the development phase. Contactings of individual conductors among one another are no longer necessary at all given the finished sintered conductor arrangement. The manual assembly effort is drastically reduced. Since no residual stresses arise (for example due to a curvature or coiling) that can cause deformations in the sealing process, a higher precision is achieved.

Further advantages, features and details of the invention result using Figures from the exemplary embodiments of the invention described in the following. Thereby shown are:

Figure 1 a drawing of components of a system for laser sintering,

Figure 2 sub-coils and an insulation layer with coolant tubes of a gradient coil system together with a casting mold for the gradient coil system and

Figure 3 a cross-section of a hollow conductor of a conductor arrangement of the gradient coil system.

At the beginning of a method for production of a conductor arrangement by means of laser sintering, a three-dimensional design plan of the desired course of the electrical conductors of the gradient coil system exists. This three-dimensional design plan is prepared for the laser sintering such that it is divided up into parallel layers with a typical thickness of 50 – 100 μm. The design plan so prepared is passed to a laser sintering system 10 in which a powder layer 18 of a selected metal powder with high electrical conductivity (in particular copper powder or aluminum powder) is generated corresponding to the layer thickness on a construction platform 12 of the laser sintering system 10. This powder layer 18 thereby represents a first layer of the design plan within which electrical conductors run, whereby the laser sintering system 10 sinters or, respectively, fuses the metal powder in the region of the electrical conductors via a laser beam 15 of high energy. Via variation of the process parameters it is intended to fuse the metal powder optimally without pores in order to achieve the properties of the solid material to the greatest possible extent. The construction platform 12 is subsequently lowered by one layer thickness and a second powder layer 19 (corresponding to the layer thickness) is applied and also sintered with the laser beam 15 in this metal powder layer 19 as described in the preceding. Sintered sub-regions situated atop one another thereby connect. Thae application of a metal

powder layer, the sintering with the laser beam 15 and the lowering of the construction platform 12 are thereby repeated until all layers of the design plan are finished. At the end of the aforementioned production cycle, the generated conductor arrangement is completely surrounded by metal powder and the finished conductor arrangement is to be extracted from the surrounding metal powder. More detail regarding methods and devices for laser sintering is, for example, described in DE 195 14 740 C1, DE 100 53 742 A1, EP 1 234 625 A1 etc.

Figure 2 exemplarily shows two sub-coils 21 and 22 arranged on frustum-like surfaces of a transversal gradient coil of a gradient coil system that has been generated via laser sintering in that, according to the method described in the preceding, the frustums are partitioned into slice-like layers and the design plan forming the basis of the sub-coils has been finished layer for layer.

For a short production time, in one embodiment the laser sintering system 10 is equipped with a plurality of lasers 14 that expose simultaneously. Exposure strategies are thereby used that effect an optimally high material density, i.e. that locally melt the metal powder completely. Furthermore, exposure strategies are used that prevent distortion appearances.

In the case of a plurality of individual coils of the conductor arrangement that are free of an electrical connection within the gradient coil system are simultaneously generated with the method described in the preceding, to prevent the fundamental problem that the individual coils could mutually shift given the extraction from the metal powder it is counteracted in that filigree web are additionally sintered in the production method, which filigree webs connect the individual coils with one another and can easily be removed after the extraction from the metal powder due to provided predetermined break points within the webs. A web 25 is exemplarily shown between the sub-coils in Figure 2.

In one embodiment, fixing and/or adjustment elements 26 are additionally sintered that effect an automatic adjustment of the sintered structure given usage in a casting mold 30 with corresponding counterparts 32.

The conductor arrangement extracted from the metal powder is further processed as follows: planar insulation layers are inserted between individual coils of the conductor structure. Coolant elements arranged in a meandering shape on a carrier plate are inserted between the individual coils. In this regard Figure 2 exemplarily shows one of the insulation layers 28 together with a coolant tube 29 arranged thereupon for the sub-coil 21. The conductor arrangement, inclusive of the insulation layer and cooling elements, is inserted into the casting mold 30. An electrical insulation and mechanical fixing is achieved via a casting of the free spaces remaining between the conductor arrangement with a casting resin advantageously containing filler material and subsequent hardening. The casting with a casting resin based on epoxy resin thereby preferably ensues under vacuum and if applicable with subsequent pressurization.

In an embodiment, at least parts of the electrical conductor arrangement according to Figure 3 are generated as hollow conductors so that the hollow conductor 23 can be directly cooled with a coolant flowing through it and, if applicable, additional cooling elements in the gradient coil system can be omitted.